

## Nuclear Logging

### Compensated Z-Densilog (ZDL) Service

#### Measure formation bulk density and determine lithology

The Compensated Z-Densilog™ (ZDL™) service provides formation bulk density (Pb) and photoelectric absorption index (Pe) data. These measurements allow evaluation of complex formations to determine their lithology and porosity. Because the photoelectric absorption of gamma rays depends strongly on atomic number, the measured values of Pe are directly related to the formation's composition. The Pe measurement is not significantly dependent on porosity or fluid content, making it particularly useful in determining formation lithology.

Integrated features of the ZDL service include scintillation detectors for increased count rates and improved repeatability, 256-channel dual-spectrum recording for advanced signal processing, real-time gain compensation for temperature-related changes in detector response, compensation of bulk density for variable mudcake composition and thickness, and Dewar flasks that protect heat-sensitive downhole electronics for use in higher-temperature wells.

A single-axis motorized caliper that is an integral part of the tool provides a continuous caliper curve.

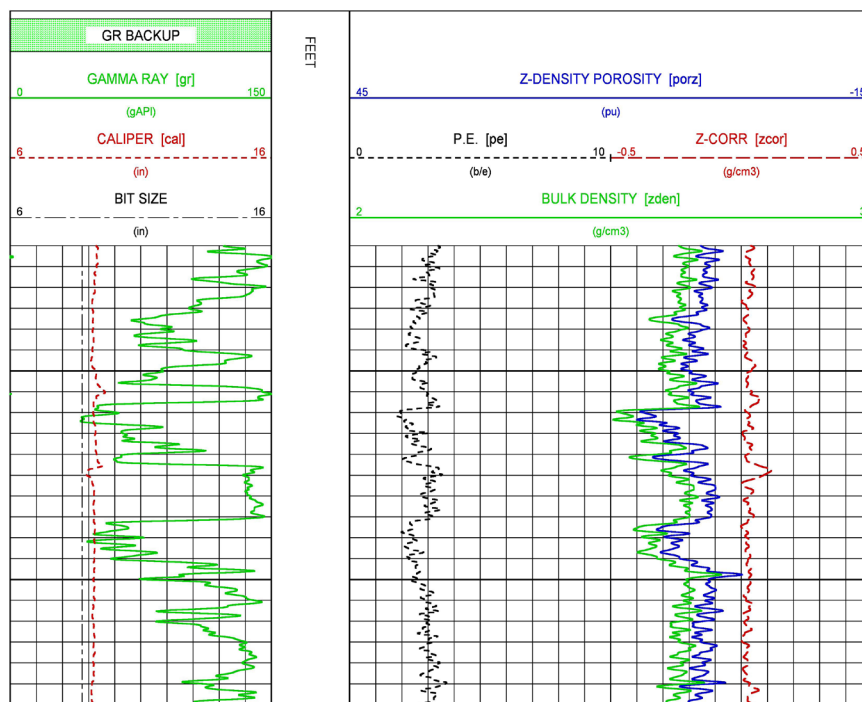
#### Applications

- Quantify formation density and porosity values
- Gather surface seismic tieback data
- Identify lithology

#### Specifications—Series 2234

Description	Specification	
Diameter	4.88 in.	123.8 mm
Pressure rating	20,000 psi	137.9 MPa
Temperature rating	350°F	177°C
Minimum borehole diameter	6 in.	152 mm

For variations to operating limits, contact your Baker Hughes representative.



Compensated Z-Densilog presentation with Pe for lithology identification and correction (zcor) for density quality flag and borehole conditions indicator.

#### Features and benefits

- Optimized source-to-detector spacing
  - Allows deeper-reading measurements
- Long-spaced and short-spaced spectrums
  - Optimizes thermal compensation
  - Improves bed-boundary resolution
- Articulated pad design
  - Improves data quality in rugose boreholes
  - Enhances data integrity in enlarged boreholes

## Nuclear Logging

### Compensated Neutron (CN) Log Service

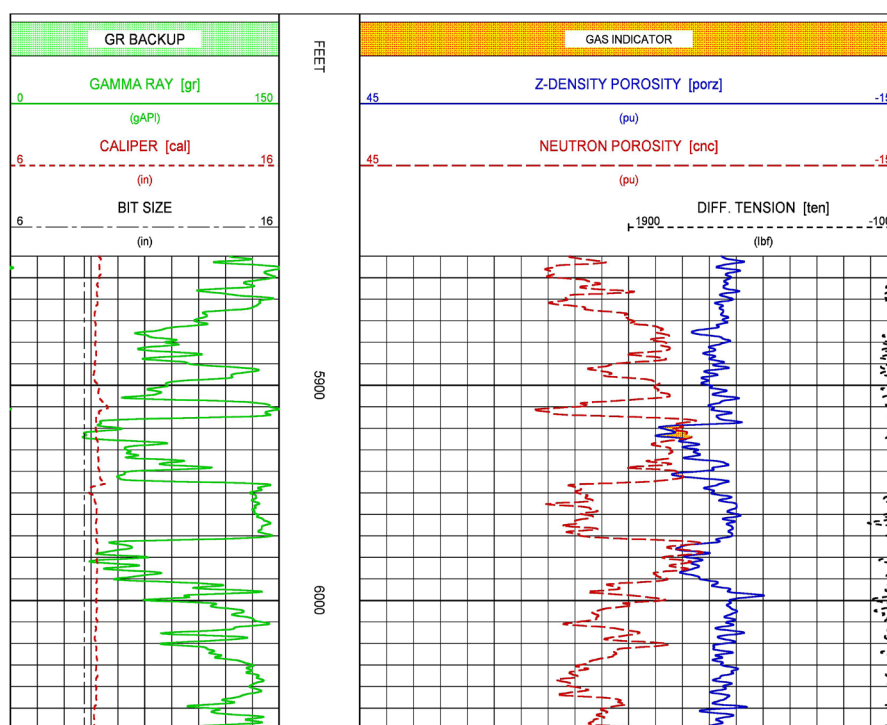
Measure neutron porosity to resolve lithology and gas identification

Combining the Compensated Neutron™ (CN™) service with a density or an acoustilog survey provides accurate porosity values, shale content, and lithological information. The relationship of the measurements often makes it possible to distinguish gas zones from oil or water zones by comparing a neutron log to another porosity log or to a core analysis.

The CN instrument uses a source and two-detector configuration. The surface system calculates the apparent porosity, using the ratio of the count rates from the two detectors.

The CN service has fewer borehole effects than other types of neutron logs. This instrument design and characterization are useful in rough or washed-out boreholes.

Neutron tools respond to the amount of hydrogen per unit volume of formation or hydrogen index. Gas and some oils have a much lower hydrogen index than water, and the tool responds to the reduced hydrogen content by indicating a lower apparent porosity. In gas zones, the apparent porosity will read lower than in water zones of the same porosity to produce a “gas effect” on the logs.



Compensated Neutron log presentation with neutron porosity combined with density porosity data for determining lithology and identifying potential gas zones.

### Applications

- Determine formation porosity
- Identify gas
- Resolve lithology

### Features and benefits

- Optimizes shielding for focused acquisition
  - Improves formation response characteristics

- Fully characterized model in various hole sizes
  - Allows wider operating range in difficult borehole conditions
- Real-time correction routines
  - Accurately compares other data for efficient analysis

### Specifications—Series 2446

Description	Specification	
Diameter	3.63 in.	92.1 mm
Pressure rating	20,000 psi	137.9 MPa
Temperature rating	350°F	177°C
Minimum borehole diameter	4.75 in.	121 mm

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## Nuclear Logging

### Gamma Ray (GR) Log

#### Identify reservoir rocks suitable for hydrocarbon production

The Gamma Ray (GR) log measures the natural radioactivity of the formation being surveyed. The intensity of radiation indicates the rock type present along the wellbore. Our GR log has flexible analog and digital varieties that can be combined with other instruments, including downhole seismic applications. The GR log can be run in any liquid- or air-filled hole, either cased or uncased. In cased holes, a casing collar log can also be recorded simultaneously.

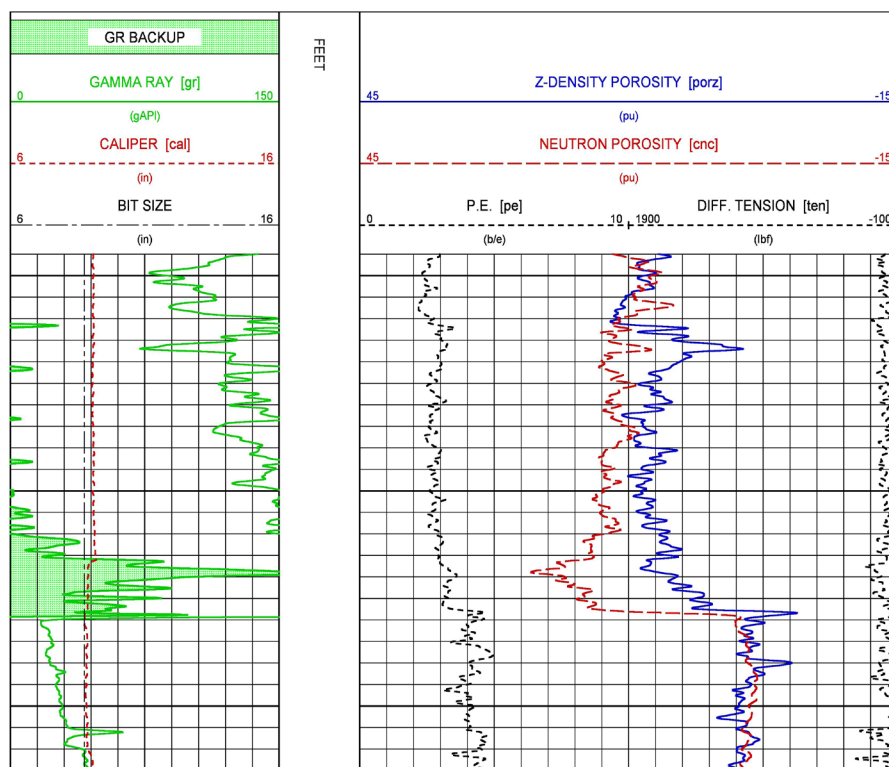
Radioactive elements are heavily concentrated in shales that demonstrate very low permeability and a higher GR response reading. The GR curve usually correlates with the spontaneous potential curve in the permeable zones.

#### Applications

- Determine formation profiles
- Estimate shale content
- Identify potential reservoir rocks for production

#### Features and benefits

- High vertical resolution
  - Determines sharp bed boundary
  - Improves net-to-gross calculations



Gamma Ray log presentation with density/neutron porosity data identifying reservoir section with subsequent highly radioactive zone in caprock.

### Specifications—Series 1330

Description	Specification	
Diameter	3.375 in.	85.7 mm
Pressure rating	20,000 psi	137.9 MPa
Temperature rating	350°F	177°C
Minimum borehole diameter	4.75 in.	121 mm

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## Nuclear Logging

### Digital Spectralog (DSL) Service

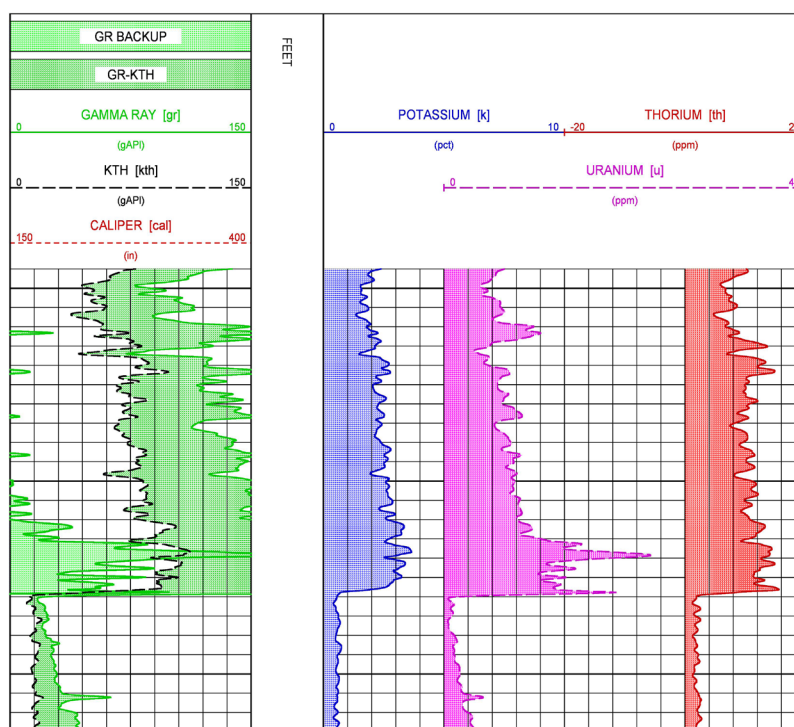
#### Identify radioactive elements in gamma ray spectrum response

Measuring the discrete energy of each gamma ray detected, as well as total gamma rays, is the defining value of the Digital Spectralog™ (DSL™) and combined Digital Gamma Ray (DGR) service. By separating the total gamma ray signal into its components, the DSL service locates fracture zones, identifies the lithology of subsurface formations, measures bed thickness, correlates zones of interest between wells, and makes qualitative estimates of formation permeability.

Improved data acquisition routines allow the DSL service to operate at three times the logging speed of the standard spectralog instrument without loss of statistical precision. The DSL service can be used with any other openhole logging instruments.

Discriminating the total gamma ray signal into discrete energy levels, or windows, infers the individual amounts of potassium (K), uranium (U), and thorium (Th). Virtually all gamma radiation detected by downhole instruments classify into one of three categories. As a result, various lithology uncertainties can be resolved that often exist when only the total gamma ray signal is used.

For example, given a high total gamma ray count over a 40-ft interval, the signal could be indicative of a shale zone. If that signal comprised mainly uranium gamma rays, it could indicate a fault plane where uranium-carrying fluid had migrated.



Digital Spectralog presentation identifying increased uranium content in highly radioactive zone above reservoir rock section.

#### Applications

- Determine clay type and content
- Identify potential fracture zones
- Locate uranium by product buildup in a cased well
- Identify depleted zones and water encroachment

#### Features and benefits

- High vertical resolution
  - Identifies uranium from geological faults
  - Improves net-to-gross calculations
- Fast data acquisition
  - Optimizes rig time

#### Specifications—Series 1329

Description	Specification	
Diameter	3.63 in.	92.1 mm
Pressure rating	20,000 psi	137.9 MPa
Temperature rating	350°F	177°C
Minimum borehole diameter	4.75 in.	121 mm

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